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(54) **PUMP ASSEMBLY**

(57) The present disclosure is directed to a pump assembly (1) comprising

- a rotor shaft extending along a rotor axis (R),
- a pump base (3),
- a pump housing (5),
- a motor housing (9) enclosing a motor for driving the rotor shaft, and
- motor stool (7) comprising a motor coupling portion (13) and a pump coupling portion (15),

wherein the pump housing (5) encloses one or more impeller stages (10) arranged between the motor stool (7) and the pump base (3), wherein the motor stool (7) is clamped to the pump base (3) by at least two tie rods (17), wherein the motor stool (7) comprises at least two fixation protrusions (39) each having a protrusion end (41) in the motor coupling portion (13), wherein each of the tie rods (17) is fixed to the motor stool (7) by way of a fastener (37) at least partially extending through one of the fixation protrusions (39), wherein each fastener (37) is only accessible when the motor housing (9) is decoupled from the motor coupling portion (13) of the motor stool (7).

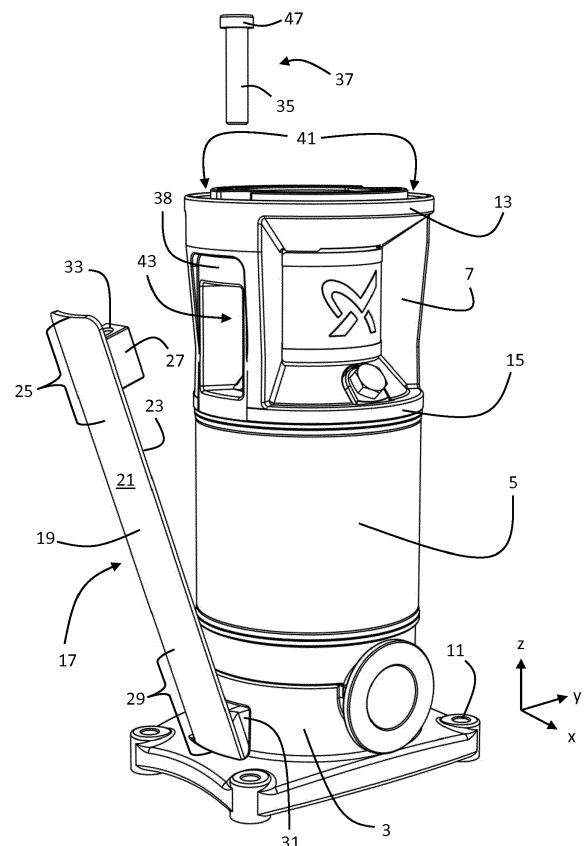


Fig. 2

Description

TECHNICAL FIELD

[0001] The present disclosure is directed to a pump assembly, in particular to a multi-stage centrifugal pump assembly.

BACKGROUND

[0002] The shape and size of a pump assembly is designed to meet certain technical requirements and specifications. In particular, multi-stage centrifugal pumps like the pumps of the Grundfos CR series come in a wide range of sizes to cover a power range of 0.1 to 100 kW. The more pumping power is needed, the larger the pump is typically designed.

[0003] Typically, such pumps comprise a rotor axis that may extend vertically or horizontally. An electric motor drives a rotor shaft extending along a rotor axis into a pump housing enclosing at least one impeller stage. A pump base typically provides a stand and/or a mounting bracket to fix the pump on a floor or a wall. Inlet and outlet flanges for mounting the pump to a piping system may be part of the pump base and/or the pump housing. The pump housing is arranged between the motor and the pump base. The more pumping power or head is needed, the more impeller stages may be stacked along the rotor axis within the pump housing. Therefore, the axial length of the pump housing typically scales with the number of impeller stages. Depending on the maximum flow the pump is supposed to be able to deliver, the radial extension of the impellers and the pump housing may be larger or smaller.

[0004] As one type of electric motor can be used for a certain range of pumps, different pumps within a certain performance range can be driven with the same type of motor. Vice versa, the same pump may be driven by a range of motors that come in different sizes. In order to adapt differently shaped pump housings to the same motor or the same pump housing to different sizes of motors, a motor stool typically serves as a mounting adapter between the motor and the pump. Thereby, standard electric motors can be used, which need not to be specifically designed to drive pumps and may be used in other fields.

[0005] It is known from EP 3 181 908 A1 to use four straps circumferentially distributed around the pump housing and extending axially alongside the pump housing for clamping the motor stool to the pump base.

[0006] In view of such known pumps, it is an object of the present disclosure to provide a pump assembly, which can be assembled more easily and is safer against unwanted disassembling.

SUMMARY

[0007] In contrast to such known pumps, embodiments of the present disclosure provide a pump assembly,

which can be mounted more easily and is safer against unwanted demounting.

[0008] In accordance with a first aspect of the present disclosure, a pump assembly is provided comprising

- a rotor shaft extending along a rotor axis,
- a pump base,
- a pump housing,
- a motor housing enclosing a motor for driving the rotor shaft, and
- a motor stool comprising a motor coupling portion and a pump coupling portion, wherein the motor coupling portion is located closer to the motor housing than the pump coupling portion and the pump coupling portion is located closer to the pump housing than the motor coupling portion,

wherein the pump housing encloses one or more impeller stages arranged between the motor stool and the pump base,

wherein the motor stool is clamped to the pump base by at least two tie rods,

wherein the motor stool comprises at least two fixation protrusions each having a protrusion end in the motor coupling portion, wherein each of the tie rods is fixed to the motor stool by way of a fastener at least partially extending through one of the fixation protrusions, wherein each fastener is only accessible when the motor housing is decoupled from the motor coupling portion of the motor stool.

[0009] Thus, the tie rods cannot be unmounted as long as the motor housing is coupled to the motor stool. This prevents unwanted demounting of the tie rods as long as the motor is still coupled to the rotor shaft. Furthermore, the assembling process is easier compared to previously known pumps. As the fixation protrusions are placed within the motor stool with a certain distance to the radial periphery of the motor stool, the motor stool can be easily placed at the pump housing before the tie rods are fixed to the motor stool by way of the fasteners extending at least partially through the fixation protrusions. The fixation protrusions may be axial inner bores in the motor stool, i.e. they may be closed towards the radial periphery of the motor stool. Alternatively, one or more of the fixation protrusions may be recesses in the motor stool that extend radially inwardly, i.e. they may be open towards the radial periphery of the motor stool. However, irrespective of whether the fixation protrusions are open or closed towards the radial periphery of the motor stool, the fastener may comprise engagement means, e.g. a bolt head or a nut, for engaging a tool like a spanner or a hex, wherein the engagement means are laterally enclosed by the motor stool and only accessible axially from the side where the motor housing is to be coupled to the motor stool, i.e. when the motor housing is actually decoupled from the motor coupling portion of the motor stool. Preferably, a motor stool end portion of the tie rods is pulled by the fastener towards the motor

coupling portion of the motor stool and away from the pump coupling portion of the motor stool. Thereby, the pump coupling portion of the motor stool is pushed towards the pump housing by a tension force conveyed by the tie rods. Accordingly, a pump base end portion of the tie rods pulls the pump base towards the pump housing, so that the pump housing is securely sandwiched between the motor stool and the pump base due to the clamping tension force conveyed by the tie rods.

[0010] Optionally, each of the tie rods may comprise a motor stool connection part at a motor stool end portion of the tie rod and a pump base connection part at a pump base end portion of the tie rod. Preferably, each of the tie rods may comprise a longitudinal panel, wherein said panel has a radially outer face and a radially inner face, wherein the motor stool connection part and/or the pump base connection part extend inwardly from the radially inner face of the panel towards the rotor axis. The panel may thus outwardly shield the motor stool connection part and/or the pump base connection part, so that they are not visible and/or accessible when the pump is fully assembled. At least a part of the radially outer face of the panel may be flush with the outer periphery of at least a part of the motor stool and/or the pump housing. Such part of the motor stool and/or the pump housing may comprise a longitudinal groove to accommodate at least a part of the panel essentially filling the longitudinal groove. This is particularly useful for pumps to be used in clean or sterile environments like the food industry, because flush and smooth surfaces are easier to keep clean and sterile.

[0011] Optionally, the motor stool may be clamped to the pump base by exactly two tie rods extending alongside the pump housing, wherein the fixation protrusions of the motor stool are located at diametrically opposite radial sides of the motor stool. The fixation of the tie rods to the motor stool by way of a fastener at least partially extending through one of the fixation protrusions allows for more tensile stress per tie rod compared to known four-strap fixation systems. Therefore, only two tie rods may be sufficient to securely hold the motor stool, the pump housing and the pump base together. This saves time for assembling the pump.

[0012] Optionally, each of the tie rods and/or the fixation protrusions may extend essentially parallel to the rotor axis. This is beneficial, because the main component of the tension force is essentially parallel to the rotor axis. However, the motor coupling portion of the motor stool may have a larger radial extension than the pump coupling portion of the motor stool, so that the motor stool may effectively widen towards the motor. It is thus possible that the tie rods and/or the fixation protrusions may not extend exactly parallel to the rotor axis.

[0013] Optionally, the motor stool may comprise at least two radially outwardly open motor stool recesses, wherein the protrusion end facing towards the motor housing is a first protrusion end, wherein each fixation protrusion comprises a second protrusion end facing to-

wards the pump base and ending in one of the motor stool recesses, wherein each of the motor stool recesses accommodates a motor stool connection part of one of the tie rods. The motor stool recess may radially outwardly merge into a longitudinal groove at the motor stool for accommodating the motor stool end of the panel of the tie rod.

[0014] Optionally, the pump base may comprise at least two radially outwardly open pump base recesses, wherein each of the pump base recesses accommodate a pump base connection part of one of the tie rods. It is advantageous that the pump base connection part, in contrast to the motor stool connection part, is not actively fixed to the pump base by way of a fastener, but passively hooked into the pump base recess of the pump base for a secure positive form locking. Thus, each pump base recess may comprise an anchor face for positive form locking with a hook face of a pump base connection part of the tie rods. Preferably, the anchor face of the pump base recess may have an angular orientation with an angle β in the range of 0° to 60° , most preferably 0° to 15° , with respect to a plane perpendicular to the rotor axis, wherein the surface normal of the anchor face has a vector component pointing radially inward towards the rotor axis and/or downwards. Likewise, the hook face of the pump base connection part may have a corresponding angular orientation with the angle β in the range of 0° to 60° , most preferably 0° to 15° , with respect to a plane perpendicular to the rotor axis, wherein the surface normal of the hook face has a vector component pointing radially outward away from the rotor axis and/or upward. The contact between the anchor face and the hook face provides for a secure positive form locking of the pump base end portion of each tie rod.

[0015] Optionally, in order to make sure that the pump base connection part cannot slip off the pump base recess, at least one of the pump base recesses may comprise a securing face for abutting against the radial outer face of the panel of the tie rod, wherein the surface normal of the securing face has a vector component facing radially inward toward the rotor axis. Preferably, the securing face is located axially further away from the pump housing than the anchor face, wherein the pump base laterally widens in the direction away from the pump housing. Preferably, the securing face is located radially more outward than the outer periphery of the pump housing. Thereby, the panel of the tie rods can be designed straight in longitudinal direction.

[0016] In some cases, it may be advantageous for the anchor face and the hook face to have an angular orientation with a zero or negative angle β in the range of 0° to -30° , with respect to a plane perpendicular to the rotor axis, with the surface normal of the anchor face having a vector component pointing radially outward and the surface normal of the hook face having a vector component pointing radially inward. In such a case, the securing face may prevent the pump base connection part from slipping off the pump base recess.

[0017] Optionally, a panel of each tie rod may lie at least partially against a radially outer face of the pump housing. Thereby, a thermal contact may provide for an enhanced heat dissipation of the pump housing via the panels of the tie rods. Optionally, in order to enhance the thermal transfer between the pump housing and the panel, the tie rod may comprise a thermally conducting pad at the radially inner face of the panel. The pad may thus be placed between the panel and the pump housing transferring heat from the pump housing to the panel which has a relatively large radially outer face to radiate heat off and to be cooled by ambient air.

[0018] Optionally, the circumferential extension of the panels of all tie rods in cumulation may cover a fraction in the range of 1/18 to 1/4 or more, preferably about 1/5 or about 1/6, of the circumference of the pump housing. Thereby, the tensile stress on the tie rods can be efficiently distributed over the width of the panels in circumferential direction. The circumferential extension of the panels may be constant or vary over their length. In case it varies over the length, the maximum of the circumferential extension of the panels of all tie rods in cumulation may cover a fraction in the range of 1/18 to 1/4 or more, preferably about 1/5 or about 1/6, of the circumference of the pump housing.

[0019] Optionally, at least one of the fasteners may comprise an engagement means, e.g. a bolt head or a nut, for engaging a tool, e.g. a spanner or a hex, wherein the engagement means is laterally enclosed by the motor stool.

[0020] Optionally, the protrusion end in the motor coupling portion may be laterally enclosed by the motor stool and may form a laterally shielded inner seat for engagement means of the fastener within the motor coupling portion of the motor stool.

[0021] Optionally, at least one face of a panel of each tie rod may be arc-shaped in a cross-sectional plane perpendicular to the rotor axis, wherein the curvature of the arc-shaped face corresponds to a curvature of a radial outer face of the pump housing. This is not only beneficial to achieve a flush transition between the panel and the motor stool for an appealing aesthetic design and easier cleaning, but also increases the stiffness of the tie rods without adding weight and material to it.

[0022] Optionally, a panel of each tie rod may be stiff against bending perpendicular to the rotor axis, so that the motor stool end of the tie rod deflects by less than 5% of the tie rod length when a nominal test weight of 1 kg is applied vertically downward to the motor stool end of the tie rod while the tie rod is fixed horizontally at the base end of the tie rod. This is beneficial for coping with the tensile stress, in particular when only two tie rods are used to clamp the motor stool to the pump base.

[0023] Optionally, each of the fasteners may comprise a bolt, wherein a motor stool connection part of each tie rod comprises a thread for receiving the bolt. The bolt may comprise an outer thread to be inserted through the fixation protrusions of the motor stool and to be crewed

into an inner thread of the motor stool connection part of the tie rod placed in the motor stool recess. Alternatively, the bolt may extend from the motor stool connection part placed in the motor stool recess through the fixation protrusions of the motor stool towards the motor housing to be fixed by a nut at the motor coupling portion of the motor stool.

[0024] Optionally, each of the protrusion ends facing the motor housing may comprise a counterbore, wherein each of the bolt heads is formed as a socket head and at least partially sunk into one of the counterbores. It is advantageous if the bolt heads do not axially protrude out of the motor coupling portion of the motor stool, because a variety of motor housings may thereby be mounted on the motor stool.

[0025] Optionally, each of the fasteners may comprise a nut with an inner thread portion, wherein a motor stool connection part of each tie rod comprises a bolt portion with an outer thread, the bolt portion extending through the fixation protrusion for receiving the inner thread portion of the nut located at the protrusion end facing towards the motor housing. Optionally, each of the fixation protrusions may comprise a counterbore, wherein each nut is at least partially sunk into one of the counterbores.

[0026] Optionally, a motor stool connection part of each tie rod is movable parallel to the rotor axis within a range inside a motor stool recesses, wherein an upper limit of the range is defined by a positive form locking between a hook face of a pump base connection part of the tie rod and an anchor face of a radially outwardly open pump base recess in the pump base.

[0027] Optionally, the pump base recess may be downwardly open so that a lower limit of the range is defined by the ground on which the pump assembly is standing.

[0028] Optionally, the pump assembly is a multi-stage centrifugal pump assembly.

SUMMARY OF THE DRAWINGS

[0029] Embodiments of the present disclosure will now be described by way of example with reference to the following figures of which:

Fig. 1a-c show perspective views on three examples of pump assemblies according to the present disclosure.

Fig. 2 shows a perspective view on the example as a first embodiment shown in Fig. 1b without a motor housing and one of the tie rods being installed.

Fig. 3 shows a longitudinal cut view through the yz-plane on the example shown in Fig. 2.

Figs. 4a and 4b show perspective views on a second embodiment of a pump assembly according to the present disclosure in different phases of one of the tie rods being installed.

Fig. 4c shows a top view on the example as shown in Fig. 4a.

Fig. 5 shows partly a sectional view on the examples as shown in Fig. 1 b and 4b.

Fig. 6a-e show simplified longitudinal cut views through the yz-plane as shown in Fig. 2 in five phases of assembling the first embodiment of a pump assembly according to the present disclosure;

Fig. 7a-e show simplified longitudinal cut views through the yz-plane as shown in Figs. 4a,b in five phases of assembling the second embodiment of a pump assembly according to the present disclosure; and

Fig. 8a-e show simplified longitudinal cut views through the yz-plane in five phases of assembling a third embodiment of a pump assembly according to the present disclosure.

DETAILED DESCRIPTION

[0030] Fig. 1a-c show pump assemblies 1 in form a multi-stage centrifugal pump assemblies. The shown pump assemblies 1 all have a rotor axis R extending along a vertical direction z. The horizontal plane perpendicular to the vertical direction z is spanned by the vectors x and y, so that xyz define a right-handed Cartesian coordinate system. It should be noted that the right-handed Cartesian coordinate system may have any orientation, e.g. in a horizontal pump setup the rotor axis R may alternatively extend along a horizontal axis in the xy-plane. The terms "upper" or "lower" herein refer to the position in a vertical pump setup and shall be construed as relative positions along the rotor axis R in a horizontal or other pump setup.

[0031] Each of the pump assemblies 1 comprises a pump base 3 (in the shown vertical pump setup at the bottom of the pump assembly 1), a pump housing 5, a motor stool 7 and a motor housing 9 (in the shown vertical pump setup at the top of the pump assembly 1) enclosing a motor. The motor drives an inner rotor shaft (not shown) extending along the vertical rotor axis R into the pump housing 5. The pump housing 5 rests on the pump base 3 and encloses a stack of two impeller stages 10 arranged between the motor stool 7 and the pump base 3. The pump base 5 serves as a stand for the pump assembly 1 and provides lugs or bores 11 for fixing the pump assembly 1 to the ground it stands on. The motor housing 9 is mounted on the motor stool 7 that serves as a mounting adapter between the pump housing 5 and the motor housing 9. The motor housing 9 is fixed to the motor stool 7 by accessible bolts 8. The motor stool 7 thus comprise a motor coupling portion 13 at a first (upper) axial end to attach the motor housing 9 and a pump coupling portion 15 at a second (lower) axial end to attach the pump hous-

ing 5.

[0032] The example shown Fig. 1b differs from the example shown in Fig. 1a that the embodiment in Fig. 1b comprises a larger motor housing 9 with a more powerful motor and one more impeller stage 10, i.e. in total three (see Fig. 3), than the example shown in Fig. 1a. The motor coupling portion 13 of the motor stool 7 is therefore adapted to the larger motor housing 9. The pump base 3, the diameter of the pump housing 5 and the pump coupling portion 15 of the motor stool 7 are basically identical between these two examples. The motor housing 9 in Fig. 1a has a smaller lateral extension than the motor coupling portion 13 of the motor stool 7. The motor housing 9 in Fig. 1b has a larger lateral extension than the motor coupling portion 13 of the motor stool 7. A certain range of motor sizes can be mounted on the same motor stool 7. The pump assembly 1 shown in Fig. 1b is able to provide a higher maximal fluid flow and head than the pump assembly 1 shown in Fig. 1a. The motor housing 9 and the motor may be standard multi-purpose electric motors that may be not only be suitable to drive a rotor shaft of a pump, but may be applicable for other purposes as well.

[0033] Fig. 1c shows an example with a pump housing that is longer in the direction of the vertical rotor axis R, because it encloses even more impeller stages 10. Thereby, the pump assembly 1 shown in Fig. 1c is able to provide a higher maximal fluid flow and a higher head than the examples shown in Fig. 1a and 1b. Furthermore, the motor housing 9 in Fig. 1c is larger than in Fig. 1b to enclose a more powerful motor than in Fig. 1b. The motor stool 7 differs also from Figs. 1a and 1b, because the motor housing 9 has such a wide lateral extension that the motor coupling portion 13 provides for a mounting flange having a substantially larger diameter than the pump coupling portion 15 of the motor stool 7. The pump housing 5 and the impeller stages 10 have the same diameter in all three examples. The pump base 3 is identical for all three examples. However, the diameter of the pump housing 5, the impeller stages 10 and the pump base 3 may differ between different examples depending on the requirements of the pump assembly 1.

[0034] In all three examples shown in Figs. 1a-c, the motor stool 7 is clamped to the pump base 3 by exactly two essentially identical tie rods 17, of which only a radially outer face 21 of a steel panel 19 of one of the tie rods 17 is visible in Fig. 1a-c. The other tie rod 17 is located at the diametrically opposite radial side of the pump housing 5. The tie rods 17 are under tensile stress to pull, with an upper motor stool end portion 25 of the tie rods 17, the upper motor coupling portion 13 of the motor stool 7 downwards and to thereby press the lower pump coupling portion 15 of the motor stool 7 downward against the pump housing 5. A lower pump base end portion 29 of the tie rods 17 is hooked into the pump base 3 and pulls the pump base 3 upward against the pump housing 5. The pump housing 5 is thus securely sandwiched between the motor stool 7 and the pump base 3.

[0035] Fig. 2 shows the example of Fig. 1b as a first embodiment with one tie rod 17 disassembled and without the motor housing 9. This is, because the tie rods 17 cannot be disassembled as long as the motor housing 9 is coupled to the motor stool 7. This adds safety to the pump assembly 1. As shown in Fig. 2, the tie rod 17 comprises a longitudinal panel 19 extending essentially straight in its longitudinal direction. The panel is curved or arc-shaped in a plane perpendicular to its longitudinal direction, wherein the curvature essentially corresponds to the curvature of the outer periphery of the pump housing 5. The panel 19 is thus very stiff and not flexible. The panel 19 comprises a radially outer face 21 that is visible when the pump assembly 1 is fully assembled and a radially inner face 23 that at least partially lies at the pump housing 5 when the pump assembly 1 is fully assembled. A thermal contact, possibly direct or enhanced by a thermally conductively pad intermediately placed between the panel 19 and the pump housing 5, provides for a good heat dissipation of the pump housing 5. The circumferential extension of the panels 19 is significantly larger than straps known in the prior art. The sum of the circumferential extension of the panels 19, which is for each panel 19 essentially constant over the length of the panel 19, covers a fraction in the range of 1/18 to 1/4 or more, preferably 1/6 or 1/5, of the circumference of the pump housing 5. As shown in Fig. 5, an angle γ of circumferential extension of one panel 19 is here 38° , which results in a total circumferential extension of both panels of 76° , i.e. $\sim 1/5$ of the circumference. Thereby, the tensile stress on the tie rods 17 can be efficiently distributed over the width of the panels 19 in circumferential direction.

[0036] At an upper motor stool end portion 25 of the tie rod 17, the tie rod 17 comprises a motor stool connection part 27 extending radially inward from the radially inner face 23. The motor stool connection part 27 may be made of steel and welded to the radially inner face 23 of the steel panel 19. Similarly, and better visible in Fig. 3, the tie rod 17 comprises, at a lower pump base end portion 29 of the tie rod 17, a pump base connection part 31 extending radially inward from the radially inner face 23. The pump base connection part 31 may also be made of steel and welded to the radially inner face 23 of the steel panel 19. In this first embodiment, the motor stool connection part 27 comprises an inner thread 33 for receiving an outer thread 35 of a fastener 37 in form of a bolt. The inner thread 33 within the motor stool connection part 27 essentially extends parallel to the longitudinal direction of the panel 19. The upper motor stool end portion 25 of the panel 19 is flush with the outer periphery of the motor stool 7 when the tie rod 17 is mounted. In order to accommodate the panel 19, the motor stool 7 comprises a longitudinal groove 38 into which the panel snugly fits to complement the outer periphery of the motor stool 7 and yield a flush surface. This is aesthetically appealing and particularly useful for pumps to be used in clean or sterile environments like the food industry, because flush and smooth surfaces are easier to keep

clean and sterile.

[0037] In this first embodiment, the motor stool 7 comprises two fixation protrusions 39 in form of inner bores each having a protrusion end 41 at the motor coupling portion 13. It is important to note that the protrusions 39 have a lateral distance to the outer periphery of the motor coupling portion 13 of the motor stool 7 so that the motor housing 9, when coupled to the motor stool 7, blocks the axial access to the upper protrusion end 41. The protrusion end 41 is thus inaccessible when the motor housing 9 is coupled to the motor stool 7. The protrusion end 41 is shielded against lateral access by the motor stool 7 itself.

[0038] As can be seen better in Fig. 3, the motor stool 7 comprises two radially outwardly open motor stool recesses 43 for accommodating the motor stool connection parts 27 of the tie rods 17. When the tie rods 17 are in an installation position as shown in Fig. 3, the inner threads 33 of the motor stool connection parts 27 are coaxially aligned with the fixation protrusions 39 of the motor stool 7. The fixation protrusions 39 have a first protrusion end 41 facing towards the motor housing 9 and a second protrusion end 45 facing towards the pump base 3 and ending in the motor stool recesses 43. The bolt of the fastener 37 is inserted from the axial top end of the motor stool 7 into the first protrusion end 41 and extends with its outer thread 35 through the fixation protrusion 41 into the inner thread 33 of the motor stool connection part 27 of the tie rod 17. The motor stool connection part 27 of each tie rod 17 is movable parallel to the rotor axis R within a range inside the motor stool recesses 43, wherein an upper stop is defined by a positive form locking between the pump base connection part 31 of the tie rod 17 and the pump base recess 49 in the pump base 3. So, the motor stool connection part 27 has some room inside the motor stool recess 43 in move parallel to the rotor axis R, so that it can be slightly pulled upward by tightening the bolt 37. Thereby, the tie rods 17 are put under tensile stress to clamp the motor stool 7 and the pump base 3 together, because the lower pump base end portion 29 of the tie rod 17 is hooked into the pump base 3 by the pump base connection part 31. A bolt head 47 in form of a socket head of the bolt is fully sunk into the first protrusion end 41 that is formed as a counterbore. Thereby, the bolt does not axially protrude out of the upper axial end of the motor stool 7, which makes the motor stool 7 more flexible to receive different kinds of motor housings 9. The bolt head 47 is an engagement means of the fastener 37 for a hex to engage with for screwing the bolt. The bolt head 47 is enclosed by the motor stool 7 so that a hex can only be applied axially from the upper side of the motor stool 7 when the motor housing 9 is decoupled. There is no access to the bolt head 47 to laterally apply a hex or another tool.

[0039] The pump base connection part 31 at the lower pump base end portion 29 of the tie rod 17 projects radially inward into a radially outwardly open pump base recess 49 of the pump base 3. In order to provide for a

secure positive form locking, each pump base recess 49 comprise an anchor face 51 for positive form locking with a hook face 53 of the pump base connection part 31. The anchor face 51 of the pump base recess 49 is inclined by an angle β in the range of 0° to 15° with respect to the horizontal xy-plane extending perpendicular to the rotor axis R. The surface normal N of the anchor face 51 has a vector component pointing radially inward towards the rotor axis R. Likewise, the hook face 53 of the pump base connection part 31 be correspondingly inclined by the angle β in the range of 0° to 15° with respect to the horizontal xy-plane extending perpendicular to the rotor axis R. The surface normal M of the hook face 53 has a vector component pointing radially outward away from the rotor axis R. The surface normal N and the surface normal M are essentially parallel with opposite vector directions. The contact between the anchor face 51 and the hook face 53 provides for a secure positive form locking of the pump base end portion 29 of each tie rod 17.

[0040] Each pump base recess 49 comprises a securing face 55 facing radially inward toward the rotor axis R for abutting against the radial outer face 21 of the panel 19 of the tie rod 17. The securing face 55 is located axially further away from the pump housing 5 than the anchor face 51. Furthermore, the securing face 55 is located radially more outward than the outer periphery of the pump housing 5. The pump base recess 49 is axially open to the bottom so that the pump base end portion 29 of the tie rod 17 can be placed into the pump base recess 49 when being inclined as shown in Fig. 2. The securing face 55 adds safety against the pump base connection part 31 slipping off its positive form fit with the pump base 3.

[0041] A second embodiment is shown in Figs. 4a-c, wherein the second embodiment has a different fastener 37 and fixation protrusions 39 than the first embodiment. The fastener 37 now comprises a nut 57 with an inner thread engaging with an outer thread of a bolt that is now part of or forms the motor stool connection part 27 of the tie rods 17. When the pump assembly 1 is fully assembled, the nut 57 is essentially positioned at the same laterally inaccessible inner seat that the upper protrusion end 41 provides within the motor stool 7 than the bolt head 47 in the first embodiment. A nut wrench or a spanner may be applied only from the top side when the motor housing 9 is decoupled from the motor stool 7. A washer 59 may be placed underneath the nut 57. In the second embodiment shown in Figs. 4a-c, the fixation protrusions 39 are radially open recesses in order to facilitate the insertion of the bolt of the motor stool connection part 27.

[0042] Figs. 6a-e show how the tie rods 17 of the first embodiment are mounted. At first, as shown in Fig. 6a, the tie rod 17 is tilted by a certain angle so that the lower pump base end portion 29 of the tie rods 17 can be fed into the pump base recess 49 of the pump base 3. Once the pump base connection part 31 is fully accommodated in the pump base recess 49 as shown in Fig. 6b, the tie rod 17 is pivoted into a vertical orientation. The motor

stool connection part 27 is thereby inserted laterally into the outwardly open motor stool recess 43 of the motor stool 7 as shown in Fig. 6c. The panel 19 of the tie rod 17 now extends essentially vertical parallel to the rotor axis R and rests at the outer periphery of the pump housing. As shown in Fig. 6d, the bolt of the fastener 37 is inserted from the top side of the motor stool 7 into the fixation protrusions 39 and screwed into the motor stool connection part 27 of the tie rod 17. The bolt head 47 is sunk into the motor coupling portion 13 of the motor stool 7 and rests at a first upper protrusion end 41 of the fixation protrusions 39 in the motor stool 7. Tightening the bolt 37 results in tensile stress along the panel 19 of the tie rods 17, which clamps the motor stool 7 and the pump base 3 together while the pump housing is securely sandwiched between them. As shown in Fig. 6e, once all tie rods 17 are fixed, the motor housing 9 can be coupled to the upper motor stool coupling portion 13 of the motor stool 9. The bolt heads 47 are inaccessible as long as the motor housing 9 is coupled to the motor stool coupling portion 13 of the motor stool 7.

[0043] Figs. 7a-e show how the tie rods 17 of a second embodiment are mounted. In contrast to the first embodiment shown in Fig. 6a-d, the bolt is now part of or forms the motor stool connection part 27 of the tie rods 17. As the fixation protrusions 39 are radially open in this embodiment, the motor stool connection part 27 can be placed into the motor stool recess 43 similarly to Figs. 6a-c. As shown in Figs. 7d, the bolt of the motor stool connection part 27 is pulled upwards to protrude from below through the fixation protrusion 39 at the first protrusion end 41 by screwing the nut 57. As shown in Fig. 7e, once all tie rods 17 are fixed, the motor housing 9 can be coupled to the upper motor stool coupling portion 13 of the motor stool 9. The nuts 57 are inaccessible as long as the motor housing 9 is coupled to the motor stool coupling portion 13 of the motor stool 7.

[0044] Figs. 8a-e show how the tie rods 17 of a third embodiment are mounted. In contrast to the second embodiment shown in Fig. 7a-d, the fixation protrusions 39 are radially closed in form of inner bores similar to the first embodiment. Therefore, slightly more room for axial motion is needed for the motor stool connection part 27 in the motor stool recess 43 and for the pump base connection part 31 in the pump base recess 49. As shown in Fig. 8c, the pump base end portion 29 of the tie rod 17 may even need to shortly protrude downwardly out of the pump base recess 49 of the pump base 3. For this, the pump assembly 1 may be manually tilted to shortly allow the necessary space between the pump base 3 and the ground on which the pump assembly 1 stands. As shown in Fig. 8e, once all tie rods 17 are fixed, the motor housing 9 can be coupled to the upper motor stool coupling portion 13 of the motor stool 9. The nuts 57 are inaccessible as long as the motor housing 9 is coupled to the motor stool coupling portion 13 of the motor stool 7.

[0045] Where, in the foregoing description, integers or elements are mentioned which have known, obvious or

foreseeable equivalents, then such equivalents are herein incorporated as if individually set forth. Reference should be made to the claims for determining the true scope of the present disclosure, which should be construed so as to encompass any such equivalents. It will also be appreciated by the reader that integers or features of the disclosure that are described as optional, preferable, advantageous, convenient or the like are optional and do not limit the scope of the independent claims.

[0046] The above embodiments are to be understood as illustrative examples of the disclosure. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. While at least one exemplary embodiment has been shown and described, it should be understood that other modifications, substitutions and alternatives are apparent to one of ordinary skill in the art and may be changed without departing from the scope of the subject matter described herein, and this application is intended to cover any adaptations or variations of the specific embodiments discussed herein.

[0047] In addition, "comprising" does not exclude other elements or steps, and "a" or "one" does not exclude a plural number. Furthermore, characteristics or steps which have been described with reference to one of the above exemplary embodiments may also be used in combination with other characteristics or steps of other exemplary embodiments described above. Method steps may be applied in any order or in parallel or may constitute a part or a more detailed version of another method step. It should be understood that there should be embodied within the scope of the patent warranted hereon all such modifications as reasonably and properly come within the scope of the contribution to the art. Such modifications, substitutions and alternatives can be made without departing from the spirit and scope of the disclosure, which should be determined from the appended claims and their legal equivalents.

List of reference numerals:

[0048]

- | | |
|----|---|
| 1 | pump assembly |
| 3 | pump base |
| 5 | pump housing |
| 7 | motor stool |
| 8 | accessible bolts for mounting the motor housing |
| 9 | motor housing |
| 10 | impeller stages |
| 11 | bores or lugs in the pump base |
| 13 | motor coupling portion of the motor stool |
| 15 | pump coupling portion of the motor stool |
| 17 | tie rods |

- | | |
|----------|--|
| 19 | panel of the tie rod |
| 21 | radially outer face of the panel of the tie rod |
| 23 | radially inner face of the panel of the tie rod |
| 25 | motor stool end portion of the tie rod |
| 5 27 | motor stool connection part of the tie rod |
| 29 | pump base end portion of the tie rod |
| 31 | pump base connection part of the tie rod |
| 33 | inner thread of the motor stool connection part of the tie rod |
| 10 35 | outer thread of a bolt |
| 37 | fastener |
| 38 | longitudinal groove of the motor stool |
| 39 | fixation protrusions of the motor stool |
| 41 | first protrusion end of the fixation protrusion |
| 15 43 | motor stool recesses |
| 45 | second protrusion end of the fixation protrusion |
| 47 | bolt head |
| 49 | pump base recess |
| 51 | anchor face of the pump base recess |
| 20 53 | hook face of the pump base connection part of the tie rod |
| 55 | securing face of the pump base recess |
| 57 | nut |
| 59 | washer |
| 25 K | surface normal of the securing face |
| M | surface normal of the hook face |
| N | surface normal of the anchor face |
| β | angle of orientation of the hook/anchor face |
| γ | angle of circumferential extension of a panel of a tie rod |
| 30 | |

Claims

- | | |
|----|---|
| 35 | 1. A pump assembly (1) comprising |
| | - a rotor shaft extending along a rotor axis (R), |
| | - a pump base (3), |
| | - a pump housing (5), |
| 40 | - a motor housing (9) enclosing a motor for driving the rotor shaft, and |
| | - a motor stool (7) comprising a motor coupling portion (13) and a pump coupling portion (15), |
| 45 | wherein the pump housing (5) encloses one or more impeller stages (10) arranged between the motor stool (7) and the pump base (3), |
| | wherein the motor stool (7) is clamped to the pump base (3) by at least two tie rods (17), |
| 50 | wherein the motor stool (7) comprises at least two fixation protrusions (39) each having a protrusion end (41) in the motor coupling portion (13), wherein each of the tie rods (17) is fixed to the motor stool (7) by way of a fastener (37) at least partially extending through one of the fixation protrusions (39), |
| 55 | wherein each fastener (37) is only accessible when the motor housing (9) is decoupled from the motor coupling portion (13) of the motor stool (7). |

2. The pump assembly (1) according to claim 1, wherein each of the tie rods (17) comprises a motor stool connection part (27) at a motor stool end portion (25) of the tie rod (17) and a pump base connection part (31) at a pump base end portion (29) of the tie rod (17). 5
3. The pump assembly (1) according to claim 2, wherein each of the tie rods (17) comprises a longitudinal panel (19), wherein said panel (19) has a radially outer face (21) and a radially inner face (23), wherein the motor stool connection part (27) and/or the pump base connection part (31) extend inwardly from the radially inner face (23) of the panel (19) towards the rotor axis (R). 10 15
4. The pump assembly (1) according to any of the preceding claims, wherein the motor stool (7) is clamped to the pump base (3) by exactly two tie rods (17), wherein the fixation protrusions (39) of the motor stool (7) are located at diametrically opposite radial sides of the motor stool (7). 20
5. The pump assembly (1) according to any of the preceding claims, wherein each of the tie rods (17) and/or the fixation protrusions (39) extends essentially parallel to the rotor axis (R). 25 30
6. The pump assembly (1) according to any of the preceding claims, wherein the motor stool (7) comprises at least two radially outwardly open motor stool recesses (43), wherein the protrusion end (41) facing towards the motor housing (9) is a first protrusion end (41), wherein each fixation protrusion (39) comprises a second protrusion end (45) facing towards the pump base (3) and ending in one of the motor stool recesses (43), wherein each of the motor stool recesses (43) accommodates a motor stool connection part (27) of one of the tie rods (17). 35 40
7. The pump assembly (1) according to any of the preceding claims, wherein the pump base (3) comprises at least two radially outwardly open pump base recesses (49), wherein each of the pump base recesses (49) accommodates a pump base connection part (31) of one of the tie rods (17). 45 50
8. The pump assembly (1) according to claim 7, wherein each of the pump base recesses (49) comprises an anchor face (51) for positive form locking with a hook face (53) of a pump base connection part (31) of a tie rod (17). 55
9. The pump assembly (1) according to claim 8, wherein in the anchor face (51) of each pump base recess (49) has an angular orientation with an angle β in the range of 0° to 60° with respect to a plane (xy) perpendicular to the rotor axis (R), wherein the surface normal (N) of the anchor face (51) has a vector component pointing radially inward towards the rotor axis (R).
10. The pump assembly (1) according to any of the claims 7 to 9, wherein at least one of the pump base recesses (49) comprises a securing face (55) for abutting against a radial outer face (21) of a panel (19) of each tie rod (17), wherein the surface normal (K) of the securing face (55) has a vector component facing radially inward toward the rotor axis (R).
11. The pump assembly (1) according to any of the preceding claims, wherein a longitudinal panel (19) of each tie rod (17) lies at least partially against a radially outer face of the pump housing (5).
12. The pump assembly (1) according to any of the preceding claims, wherein the circumferential extension of all tie rods (17) in cumulation spans over a fraction in the range of $1/18$ to $1/4$ or more, preferably about $1/6$ or about $1/5$, of the circumference of the pump housing (5).
13. The pump assembly (1) according to any of the preceding claims, wherein at least one of the fasteners (37) comprises an engagement means (47, 57) for engaging a tool, wherein the engagement means (47, 57) is laterally enclosed by the motor stool (7).
14. The pump assembly (1) according to any of the preceding claims, wherein the protrusion end (41) in the motor coupling portion (13) is laterally enclosed by the motor stool (7) and forms a laterally shielded inner seat for engagement means (47, 57) of the fastener (37) within the motor coupling portion (13) of the motor stool (7).
15. The pump assembly (1) according to any of the preceding claims, wherein at least one of the fasteners (37) comprises a bolt, wherein a motor stool connection part (27) of each tie rod (17) comprises a thread (33) for receiving the bolt (37).
16. The pump assembly (1) according to any of the preceding claims, wherein each of the fasteners (37) comprises a nut (57) with an inner thread, wherein a motor stool connection part (27) of each tie rod (17) comprises a bolt portion with an outer thread, the bolt portion ex-

tending through the fixation protrusion (39) for receiving the inner thread of the nut (57) located at the protrusion end (41) facing towards the motor housing (9).

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17. The pump assembly (1) according to any of the preceding claims,

wherein a motor stool connection part (27) of each tie rod (17) is movable parallel to the rotor axis (R) within a range inside a motor stool recess (43), wherein an upper stop is defined by a positive form locking between a hook face (53) of a pump base connection part (31) of the tie rod (17) and an anchor face (51) of a radially outwardly open pump base recess (49) in the pump base (3).

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18. The pump assembly (1) according to any of the preceding claims,

wherein the pump assembly (1) is a multi-stage centrifugal pump assembly (1).

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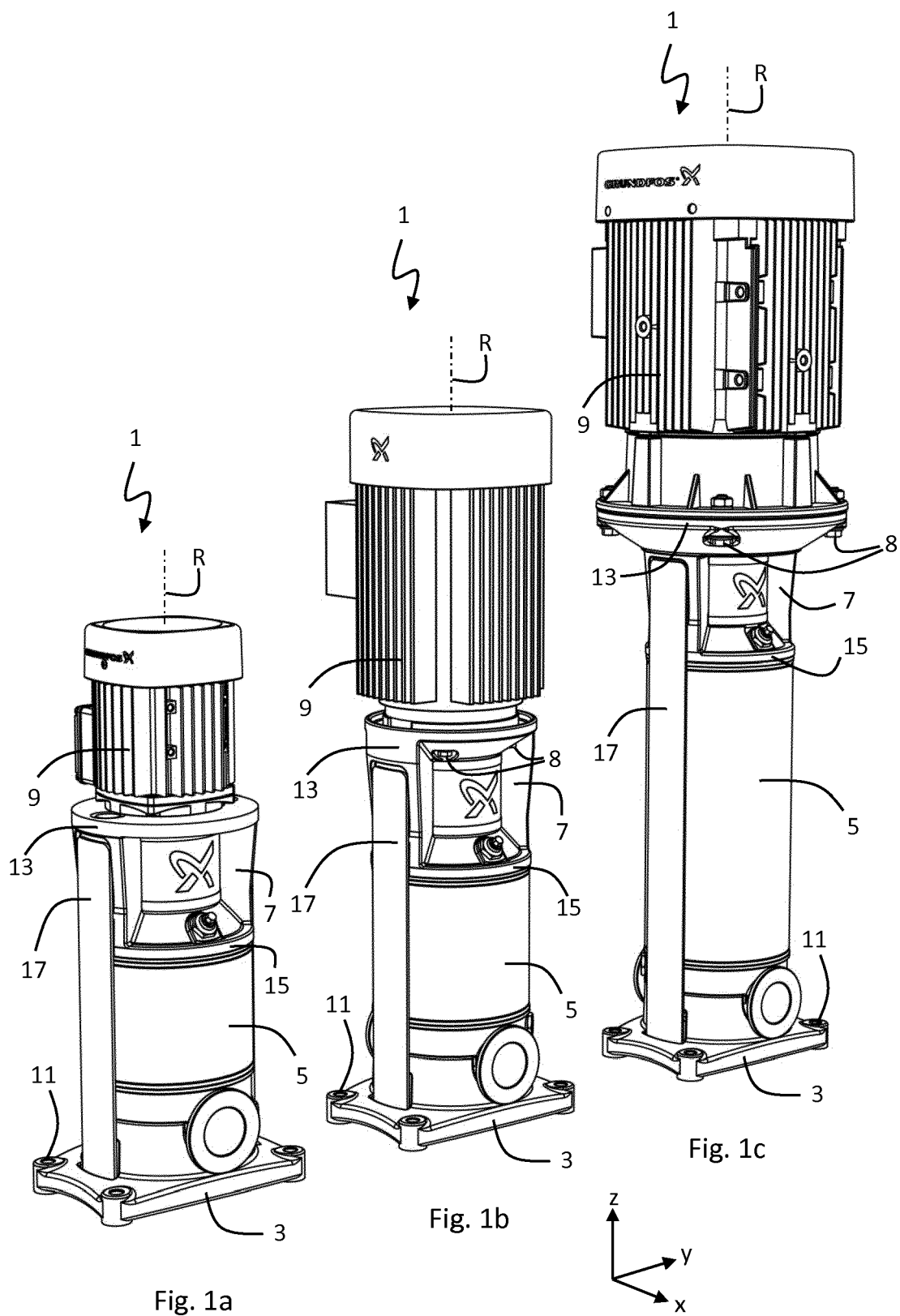
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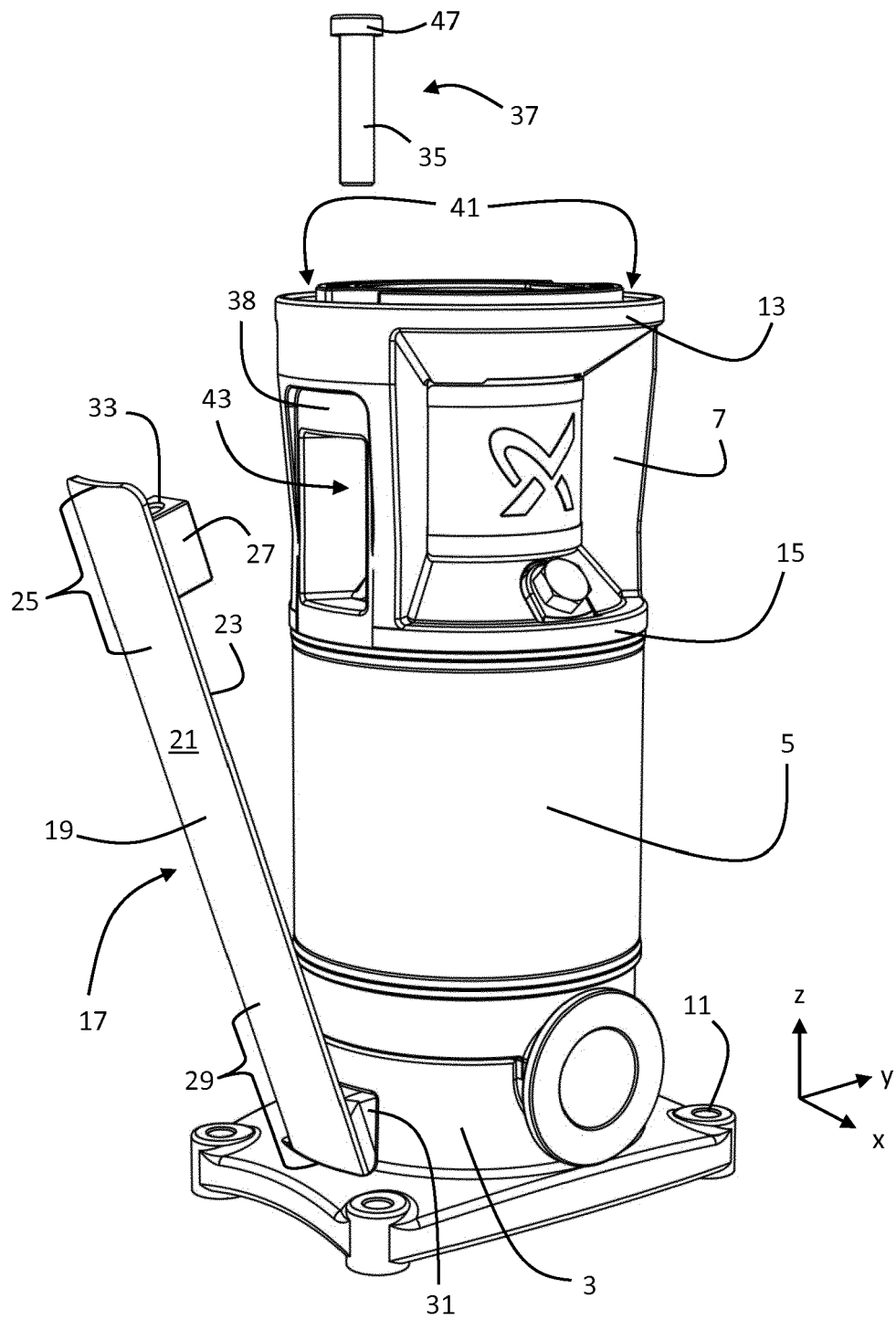


Fig. 2

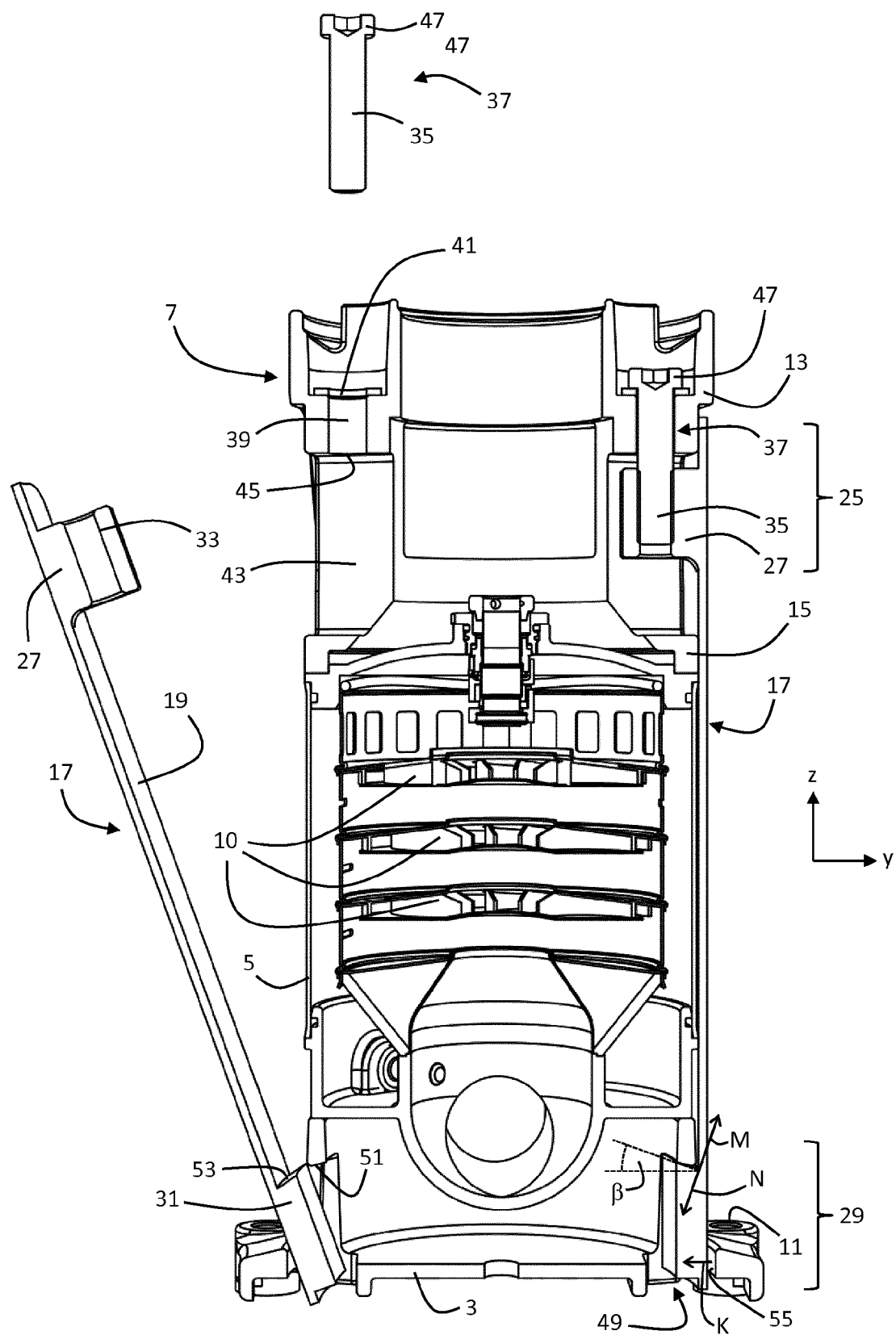


Fig. 3

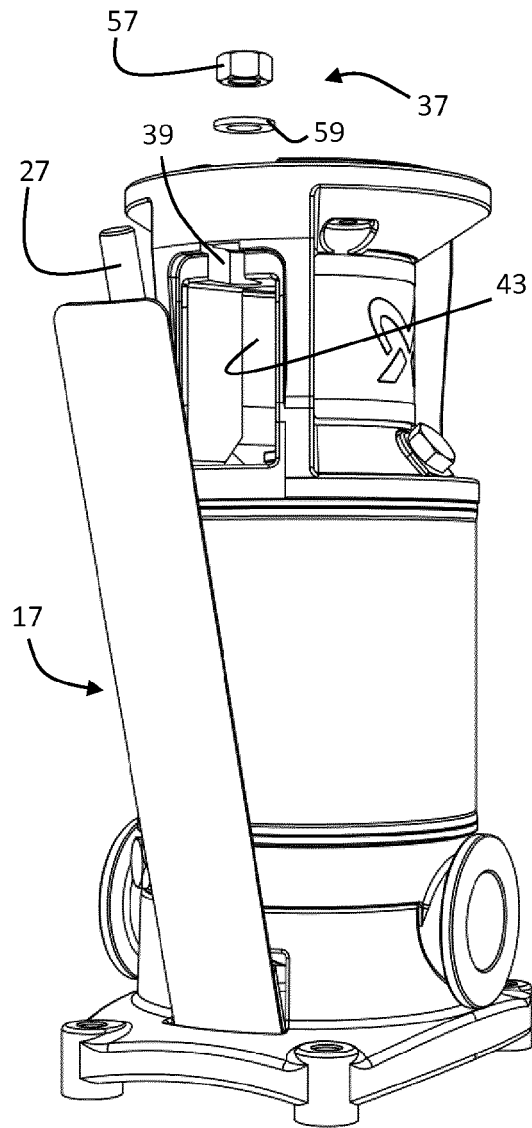


Fig. 4a

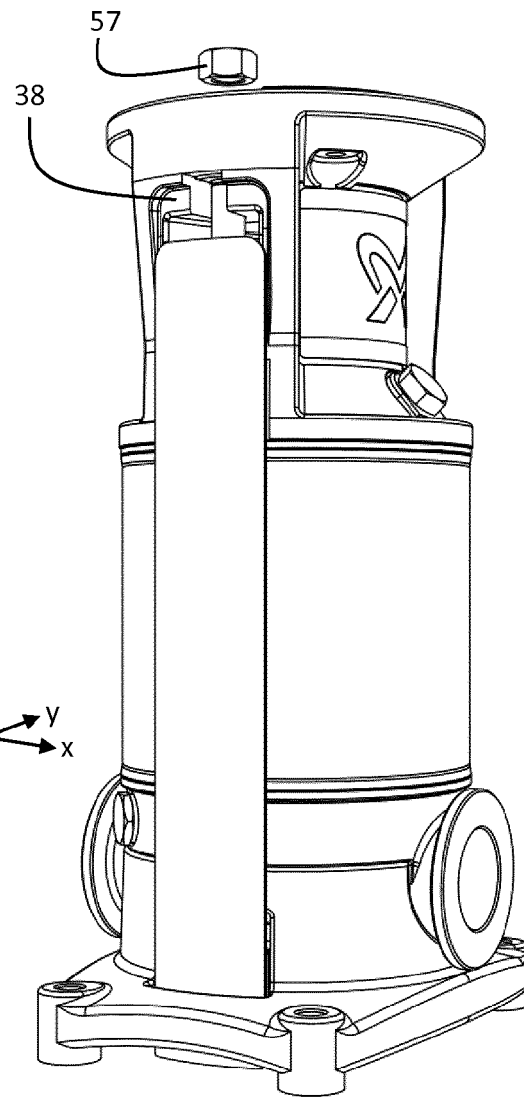


Fig. 4b

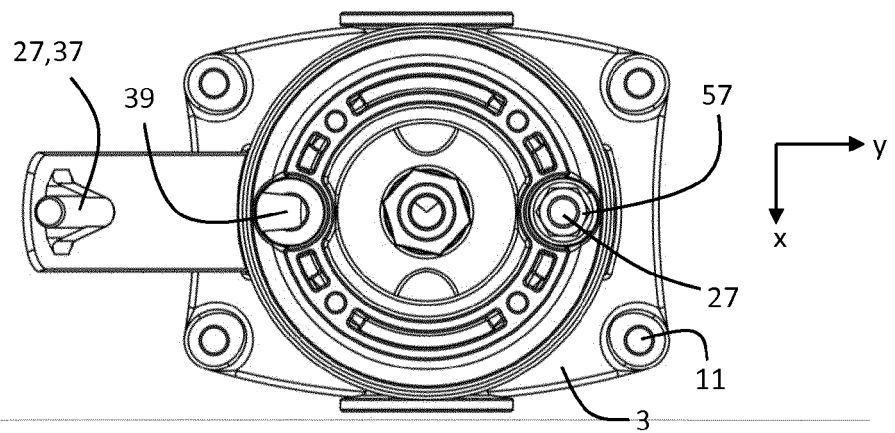


Fig. 4c

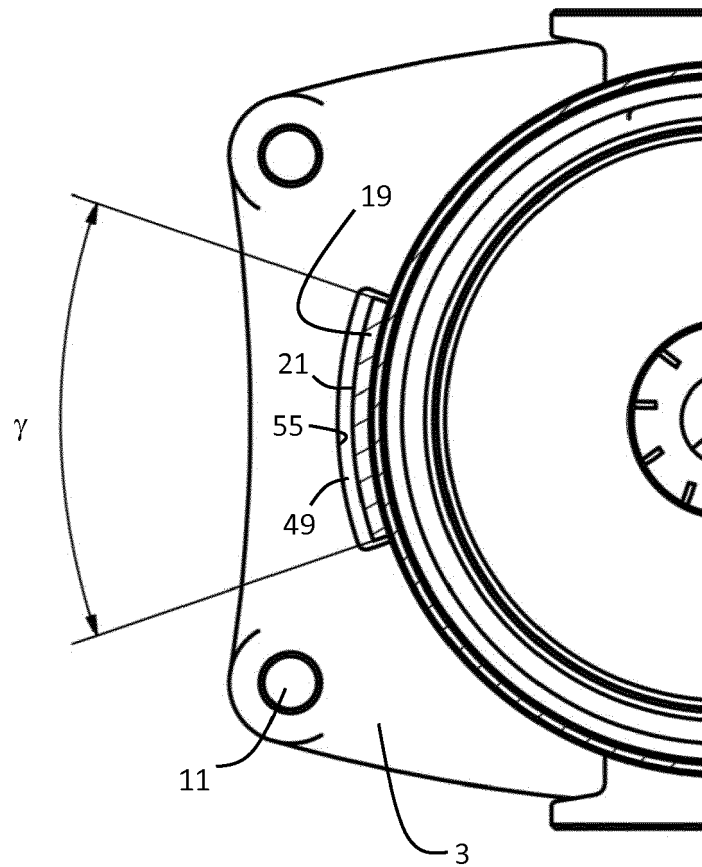


Fig. 5

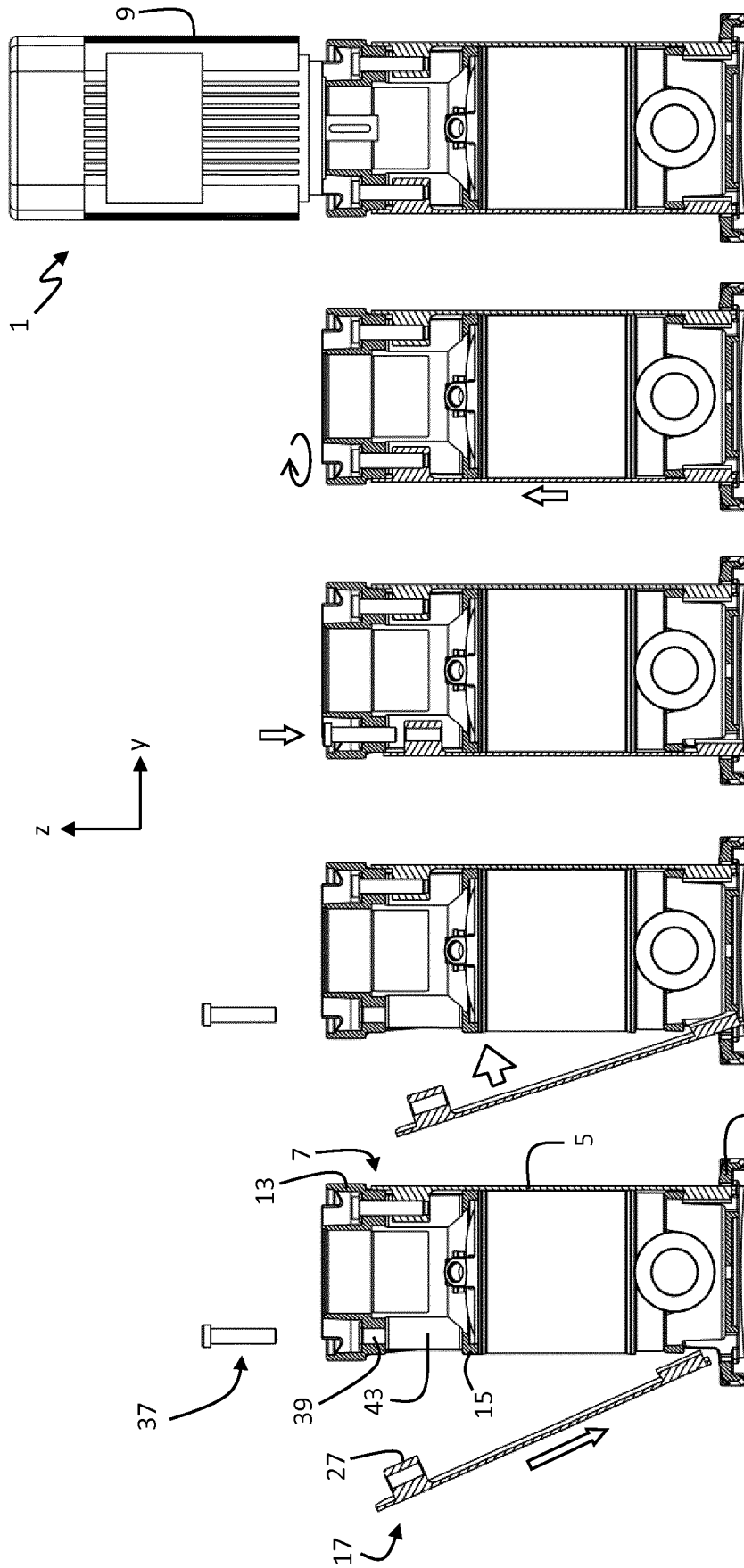


Fig. 6a

Fig. 6b

Fig. 6c

Fig. 6d

Fig. 6e

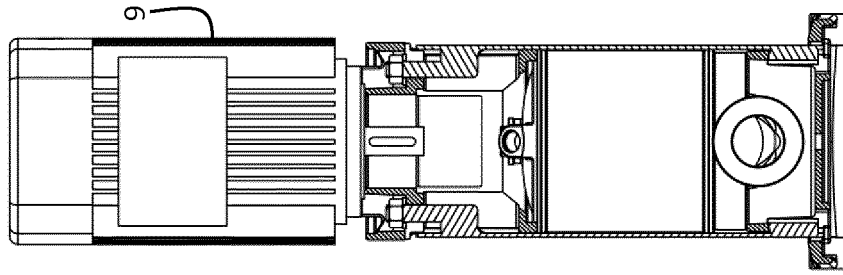


Fig. 7e

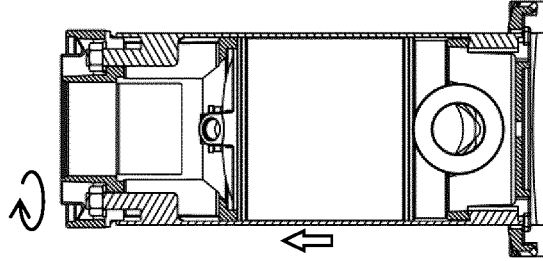
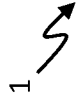


Fig. 7d

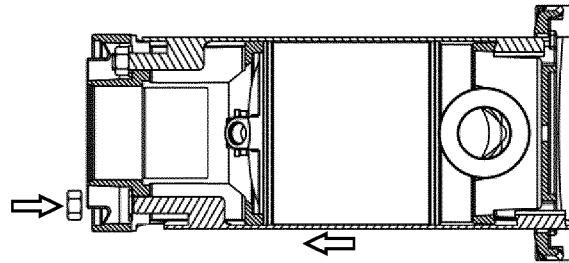


Fig. 7c

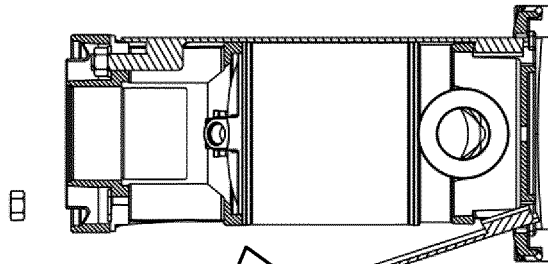
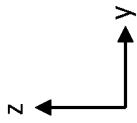


Fig. 7b

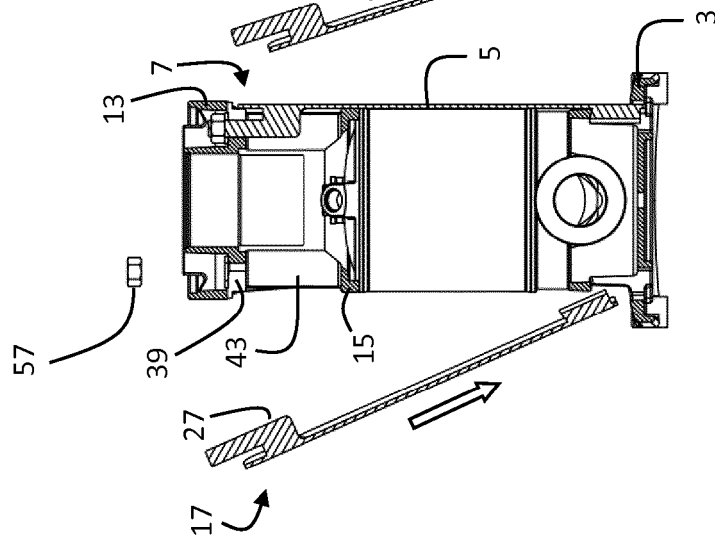


Fig. 7a

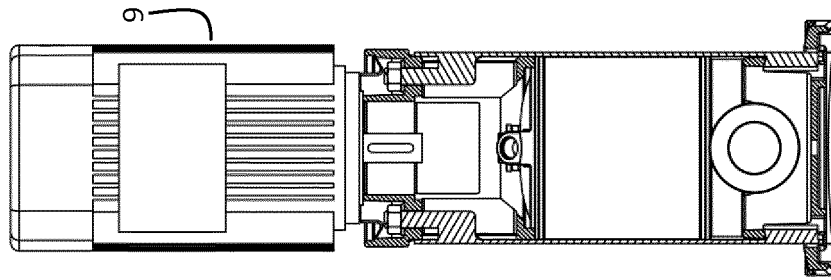


Fig. 8e

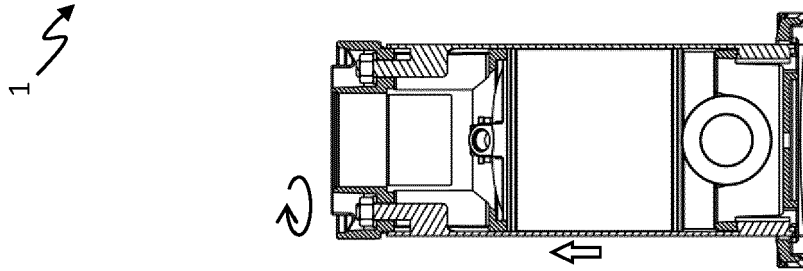


Fig. 8d

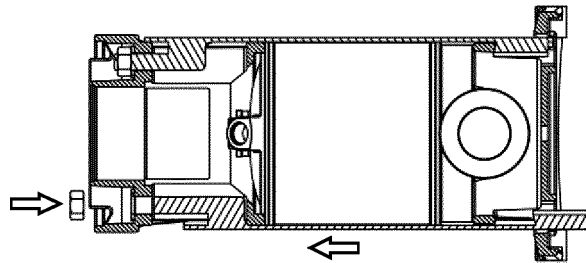


Fig. 8c

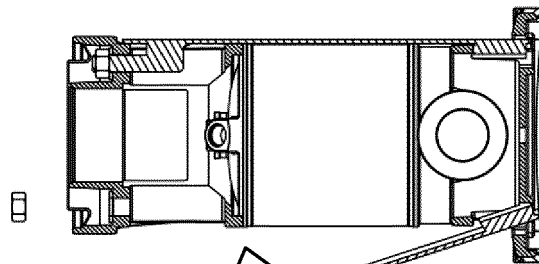


Fig. 8b

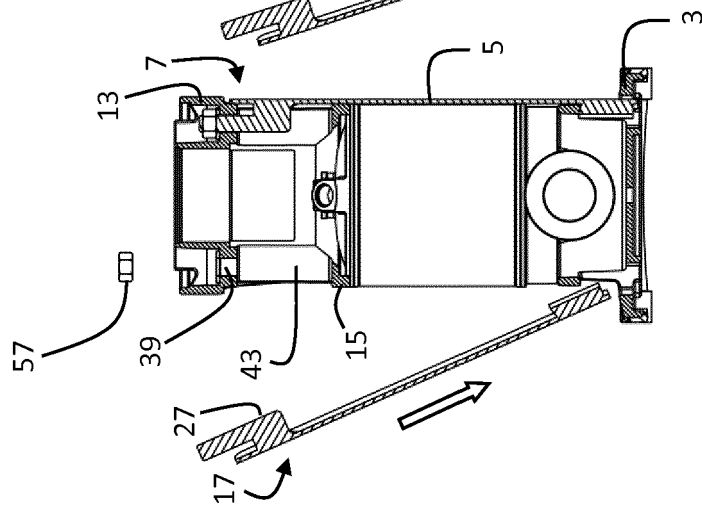
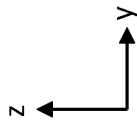


Fig. 8a





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Application Number
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			F04D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 20 May 2019	Examiner Gombert, Ralf
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/02 (P04C01)

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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